Rapid Damage Assessment and Situation Mapping: Learning from the 2010 Haiti Earthquake

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Abstract

The paper reports on the activity of the Center for Satellite based Crisis Information (ZKI) of the German Aerospace Center (DLR) in the aftermath of the devastating earthquake in Port-au-Prince, Haiti on 12 January 2010. DLR/ZKI closely coordinated with the European Global Monitoring for Environment and Security (GMES) program and the International Charter Space and Major Disasters. All DLR/ZKI damage maps are based on a specific analysis approach, including preprocessing procedures and visual interpretation on a grid-basis. As the satellite-based mapping response globally was so extensive for this event, problems resulting from the large number and inconsistency of satellite maps generated internationally are addressed. In order to avoid this kind of "mapping challenge" in future the setting-up of an international working group to elaborate global guidelines and cooperation procedures for better coherence of international satellite rapid mapping efforts for extreme events such as the Haiti earthquake is suggested.

Introduction

DLR/ZKI was strongly engaged in the international efforts to respond to the devastating Haiti earthquake of 12 January 2010, by rapidly making available analysis layers and mapping products based on satellite imagery and geo-information. The Haiti earthquake can be considered as an extreme disaster case, not only regarding the casualties and damages caused, but also concerning the amount of mapping products generated and the immense volume of earth observation data made available for this event. DLR/ZKI closely coordinated its mapping activities with two major initiatives: the International Charter Space and Major Disasters and the European Emergency Response Service (ERS) of the European Global Monitoring for Environment and Security (GMES) initiative. Furthermore, DLR/ZKI was in contact with many data suppliers, mapping initiatives and relief organizations in order to harmonize and optimize analysis results to the extent possible. Despite these efforts, the analysis work, as well as the global coordination of the satellite mapping response, turned out to be very challenging and difficult.

In the first part of the paper an overview on the coordination and management of the DLR/ZKI emergency mapping work and respective experience during the Haiti event is given. In a second part, specific aspects of the satellite based earthquake damage assessment using satellite data for the response to the Haiti event are given, and in the last section problems with the global coordination of satellite based emergency mapping efforts in case of extreme disaster events are discussed and possible improvements in the international cooperation are suggested.

Overview on Coordination and Management of the Haiti 2010 Rapid Mapping Activation at DLR

In January 2010 different mechanisms that provide rapid mapping based on Earth Observation (EO) data existed. Among those are the International Charter and GMES/ERS. While the Charter focuses on the rapid satellite tasking and data provision, the GMES/ERS has a strong service provision component (International Charter, 2010; Schneiderhan *et al.*, 2010). These two mechanisms have already worked on a bilateral coordination of common activations during 2009 (e.g., floods in Bangladesh, fires in Greece, or flash floods in Turkey) and gained experience in coordinating their activities. Thus, both initiatives combined their efforts during the Haiti activation not least because of to the large scale of the event.

Many other organizations, from web communities, NGOs, to the private sector also started to engage in mapping and analysis during the event. However, coordination, collaboration, and setting priorities became more and more difficult if not impossible due to the informal character and the diversity of the different activities in the days and weeks following the earthquake.

On 13 January 2010 the GMES/ERS was activated by the World Food Program (WFP), the Federal Office of Civil Protection and Disaster Assistance of Germany (BBK), and the Monitoring and Information Center of the European Commission (MIC), while the Charter was activated by the French Civil Protection (DSC), UN Office for Outer Space Affairs (UNOOSA) on behalf of the UN Peacekeeping Mission (MINUSTAH), Public Safety of Canada, and the American Earthquake Hazards Program of United States Geological Survey (USGS). It is important to note that the authorized user groups of these mechanisms are not identical; however, in such situation information needs are typically similar: where is the damage, what is the severity of the impact, where are the people in need, where to put up shelter and medical centers, how best to deploy relief equipment, etc.? In order to support the generation of answers to these questions, GMES/ERS and the Charter pooled their respective

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capacities and sought to generate respective mapping and geo-information products.

In a first "internalizing phase" the two mechanisms sorted out the different requests that reached them and informed each other immediately about incoming mapping requirements. This mutual communication enabled the two systems to set up common coordination teleconferences and to harmonize the efforts. During the Haiti event in 2010, the French Space Agency (CNES) took over the role of the *Project Management* on the Charter side. Daily teleconferences were held with all main players, e.g., CNES, USGS, DLR/ZKI, the French Service Régional de Traitement d'Image et de Télédétection (SERTIT), UNITAR/UNOSAT, etc.

Besides this high level international coordination, the GMES/ERS service providers internally coordinated themselves with respect to the mapping efforts to be covered as well as to the best dispatching and exchange of information and data, in order to optimize the use of the available technical and staff resources.

One of the main challenges was to keep track of all the different EO data sets that were provided. The severity of the earthquake in Haiti caused a tremendous, unprecedented data flow. Finally, more than 2.5 Terra Bytes of EO data were made available to the mapping community, posing a challenge for the service providers to screen the incoming data sets and to dispatch the analysis work. Within the GMES/ERS, the efficiency of work was mainly achieved by allocating different areas of interest to the different mapping service providers. Most GMES/ERS data sets and mapping products were made freely and publically available, while for other products the restricting license conditions of the satellite data procurement did not allow a fully open dissemination. During the Haiti event, CNES took on the task of EO data management for the Charter and provided continuous updates on the planned and acquired EO data through the so-called *Satellite Resource Tables*. Already on day three (15 January 2010) over 50 optical and 50 radar satellite data sets were made available, including archive and new acquisitions. Most of the optical imagery was suitable for analysis, due to the good weather conditions over Haiti during this period. These data sets were mainly used for the important rapid mapping efforts and to achieve the first assessments and overview maps of the situation from space. During the following days and weeks, many additional data sets were accessible, including aerial imagery and a large amount of sub-meter satellite imagery.

Another important aspect was the coordination of the technical access to the data. The USGS provided valuable resources on its Hazard Data Distribution Service (HDDS). Most of the data sets where made available either directly or by provision of the specific web links to the original data providers, in order to respect the specific license conditions. Other access points such as the knowledge portal of UN-SPIDER (**http://www.un-spider.org**) provided a centralized node for resourcing EO data and mapping results.

After generating the products, interested relief organizations and authorized users were continuously informed about the new map products becoming available using a combined GMES/ERS and Charter e-mail distribution list. These procedures for disseminating the mapping results were defined and agreed between the GMES and the Charter system and demonstrated their robustness during the Haiti event. Additionally, the mapping products were posted and mirrored on other portals to widen the range of users and to ease access to the mapping products. Two of the most important access gateways are: the website of ReliefWeb and the Virtual On-Site Operations Coordination Centre (Virtual OSOCC) of UN OCHA.

Satellite-based Earthquake Damage Assessment

Image Processing and Analysis - Considerations from an Emergency Mapping Perspective

The timeliness of data provision and the time-frame needed for data processing are key factors in rapid emergency mapping for earthquake events. Beyond the timeliness also the geometric resolution of the satellite input imagery is a key parameter, as most often only sub-meter imagery can be used for assessment of earthquake damages (Rathje and Adams, 2008). During rapid mapping activities, a compromise must be found between the response time on one hand side and the analysis depth and the mapping accuracy which need to be achieved on the other side. These aspects also have to be evaluated against specific user-requirements during an emergency. In this respect, it has become common practice to rapidly produce preliminary damage assessment maps, based on the first satellite data sets becoming available and then working towards refinement of these maps, once more data and imagery becomes available. Damage assessments in these initial maps usually have a rather coarse character and mapping detail is limited by the time constraints of the analysis. Nevertheless, despite of these limitations, the maps provide information to relief teams and support the planning and coordination of rescue operations. Upon the availability of further earth observation data and the accomplishment of a more in-depth image analysis, the maps are usually updated to incorporate new information and a refined damage assessment.

Various methodologies have been proposed for earthquake damage assessment using optical and radar earth observation data. Among the Synthetic Aperture Radar (SAR)-based methods, interferometry and differential interferometry (D)InSAR based methods have mainly been applied to study co-seismic displacements/deformations resulting from an earthquake (e.g., Aydöner and Maktav, 2009; Catita *et al.*, 2005; Chini *et al.*, 2010; Tahayt *et al.*, 2009) while for the estimation of infrastructural damages, methods exploiting changes in backscattering intensity and the related image correlation coefficient (e.g., Matsuoka and Yamazaki, 2004; Stramondo *et al.*, 2006) or a combination of backscatter intensity, phase changes, and/or ancillary data (Gamba *et al.*, 2007; Yonezawa and Takeuchi, 2001) are more prominent in literature. As an additional damage assessment technique, a combination of feature-based and pixel-based techniques was proposed by Gamba *et al.* (2006). As a general consensus, most authors have noted that the reliability of SAR-based damage estimation profits from a combination of several approaches and the use of ancillary information and optical imagery. Nevertheless, only very few of the SAR or optical imagery-based approaches have been targeted for the use in a fully operational rapid mapping environment. Frequently, a rather ideal combination of input data is needed for the methods described, which is rarely available in real emergency situations. Often the first available imagery is partially affected by clouds or suffers from poor off-nadir angles, etc., at least during the first days after the disaster event. Most SAR-based change detection approaches suffer from a lack of archive data with the same acquisition parameters as the post-crisis imagery. This also hampers the use of coherence-based change detection techniques. Furthermore, changes derived using backscatter-intensity techniques do not necessarily relate to infrastructural damages, but rather to changes resulting from different geometrical positions or other feature changes occurring between pre- and post-disaster data takes.

Several authors have presented either semi- or fully-automatic methods for earthquake damage assessment using optical data (e.g., Chini *et al.*, 2009; Sakamoto *et al.*, 2004;

Stramondo *et al.* 2006; Turker and San, 2004; Turker and Sumer, 2008). However, for various reasons, such methods have rarely been applied during rapid mapping activities. Geometric distortions and improper co-registration of optical images can result in a high false alarm rate of automatic change detection methods. Particularly for very high resolution optical satellite data, variations in solar illumination and differing off-nadir angles cause changes in building shadows between pre- and post-disaster imagery. Other sources of errors are: vegetation changes, changes in building infrastructure, and e.g., car traffic. Automatic change detection approaches will therefore potentially also detect changes that are not related to earthquake damages, particularly if there is a long time span between pre- and post-disaster acquisitions. Some authors have tried to partially avoid the occurrence of false-alarms by masking out features not related to man-made areas (Chini *et al.*, 2009; Stramondo *et al.,* 2006). Since the applicability of automatic change detection approaches is usually accompanied by several trial-and-error procedures, manual image interpretation is still the most common way to generate earthquake damage assessments rapidly (Trianni and Gamba, 2009).

Generally, there are two possibilities for visual image analysis: A mono-temporal technique, based on a single scene, taken after the event, and a multi-temporal technique, where a scene taken before the event is compared with an after-event scene. The mono-temporal approach consists of the visual recognition of the damaged elements, and is directly related to the image resolution. With data from medium spatial resolution, (around 10 m), only larger zones, of completely destroyed houses or infrastructure can be identified, while imagery of 1 m spatial resolution allows the detection of damaged buildings one by one, as the building size is considerably larger than the size of a pixel (Figure 1).

The multi-temporal approach is based on visual change detection between the two images, taken before and after the earthquake, respectively. Analyzing optical imagery, building damage of houses is associated with major changes in the structure or in the contours of a given building feature. The effective visual change detection is supported by the similarity of the two images, controlled by different parameters like resolution, illumination conditions, clouds/haze, seasons, incidence angles, etc. A large temporal gap between images can make damage identification almost impossible as new buildings might have been constructed after the pre-disaster imagery was collected.

During the Haiti earthquake assessment, DLR/ZKI mainly relied on visual interpretation for detecting building damage. The analysis steps conducted by DLR/ZKI to achieve a first damage assessment and estimation are described in the following section.

Data Availability, Mapping and Analysis Approach

In the case of earthquakes, a high spatial resolution and the fast availability of the imagery (fast reprogramming, downlink, and delivery) are the main prerequisites for providing a good basis for a meaningful damage assessment work from satellite imagery.

Timely triggering and absence of clouds allowed for example the ALOS (AVNIR), GeoEye-1, and WorldView-1 satellites to collect multispectral, very high resolution imagery over Port-au-Prince within a few hours from the earthquake event (Figure 1b). The spatial resolution of the GeoEye-1 and WorldView-2 sensors is 0.5 m in the panchromatic band and 1.65 m (1.84 m for WorldView-2) in the multispectral bands, respectively. A few days later, NOAA/Google and World Bank (World Bank-ImageCat-RIT Remote Sensing Mission) supported the collection of aerial imagery using visible, near-infrared, thermal infrared and microwave systems. It is important to note that most of these high-resolution optical data sets were made accessible to the public, free of charge in the days and weeks to follow. Airborne lidar data were also collected for various areas in Haiti and in addition to the many optical data sets, also spaceborne SAR data from the ENVISAT Advanced Synthetic Aperture Radar (ASAR) and TerraSar-X sensor were acquired. A post-seismic data pair of TerraSAR-X was processed to derive a image correlation-based shift map and co-seismic interferograms (Eineder, 2010), successfully estimating the co-seismic ground movement. For most of these data sets, additional archive imagery has been provided by

Figure 1. Post-disaster images: (a) Aerial image (© NOAA/Google and World Bank) acquired on 17 January 2010, and (b) ALOS-AVNIR-2 (© JAXA 2010) acquired on 13 October 2010.

the different satellite data providers to allow multi-temporal damage assessment.

In order to support first overview and quick orientation on the ground even before any freshly acquired post-event satellite data became available, DLR/ZKI produced 14 overview reference map sheets at the scale of 1:5000, based on publically available geo-information and archived earth observation data. The reference maps give an overview of the affected regions before the event of the earthquake. The products include: information on infrastructure (e.g., roads, harbors, and airports), settlements, points of interest (e.g., hospitals, education institutes, and potential gathering areas), administrative boundaries, population density, and the location of the earthquake epicenter. The initial road network was based on vector data provided by the United Nations Cartographic Section and the point vector data was provided by SERTIT. Following both data layers were extended and refined through a visual analysis and image interpretation of archived GeoEye satellite data.

Once the first post-event satellite imagery becomes available and to achieve best quality rapid-mapping results, the following preprocessing steps are applied to high-resolution optical satellite imagery: atmospheric corrections (Richter *et al.*, 2006), orthorectification, pan-sharpening, filtering, and contrast enhancement (Mitri, 2007; Voigt *et al.*, 2007). In order to support interactive image interpretation and visualization for map production, the images for the Haiti analysis were mainly improved by pan-sharpening and standard image contrast enhancement techniques. Accordingly, most of the DLR/ZKI Haiti map products were based on pan-sharpened GeoEye-1 imagery (Figure 2).

In the following section it is described how the pre-processed optical satellite data sets were used to achieve a systematic visual damage assessment for the capital Port-au-Prince (Plate 1) and the regions around Gressier, Grand Goave, and Petit Goave west of Port-au-Prince in Haiti.

The DLR/ZKI post-disaster damage assessment mapping products indicate zones of damage and assess the damage severity. Furthermore, these information layers were complemented by the before reference information and analysis results derived and processed for the pre-disaster reference map products. Because of the known limitations and previous experience with automatic change detection approaches as well as time-constraints and missing or incompatible archive data, visual image interpretation and analysis was adopted to generate a rapid and systematic damage assessment layer in the Haiti case.

A first phase of the damage assessment focused on identifying collapsed buildings and damage severity within the capital Port-au-Prince. In a second phase, during the days to follow the earthquake, the regions around and in Gressier, Grand Goave, and Petit Goave to the west of Port-au-Prince were included in the analysis. Often, the geometric resolution of the pan-sharpened GeoEye-1 images allows detection and labeling of damage levels even for individual houses and bridges. However, due to the wide disaster extent and the heterogeneity of the urban structures in Haiti, the rapid damage assessment was accomplished for equally-spaced grid cells of 250 m × 250 m for which an average damage level was estimated. In addition, totally destroyed objects (e.g., houses or bridges) were labeled separately during the analysis and image interpretation process. It is important to note that in terms of damage categorization, either quantitative or qualitative approaches can be applied. Quantitative damage assessment can be based on a ratio of destroyed areas or objects per designated unit reference area or number of buildings within the reference area and can be expressed by percentages. In contrast, qualitative approaches use descriptive damage categories such as "moderate/severe damages" to characterize the area assessed. Several classification schemes can be used to guide either qualitative or qualitative analysis of earthquake damage assessment.

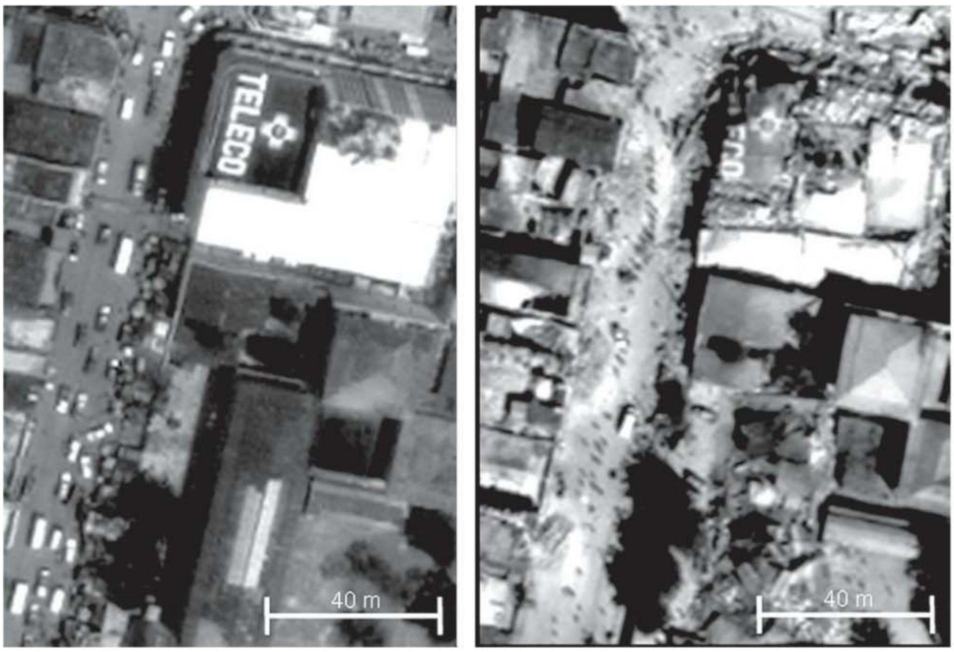


Figure 2. (a) Pre-, and (b) post- disaster images from GeoEye-1 (© GeoEye 2010), pansharpened, acquired on (a) 01 October 2009 and (b) 13 January 2010.

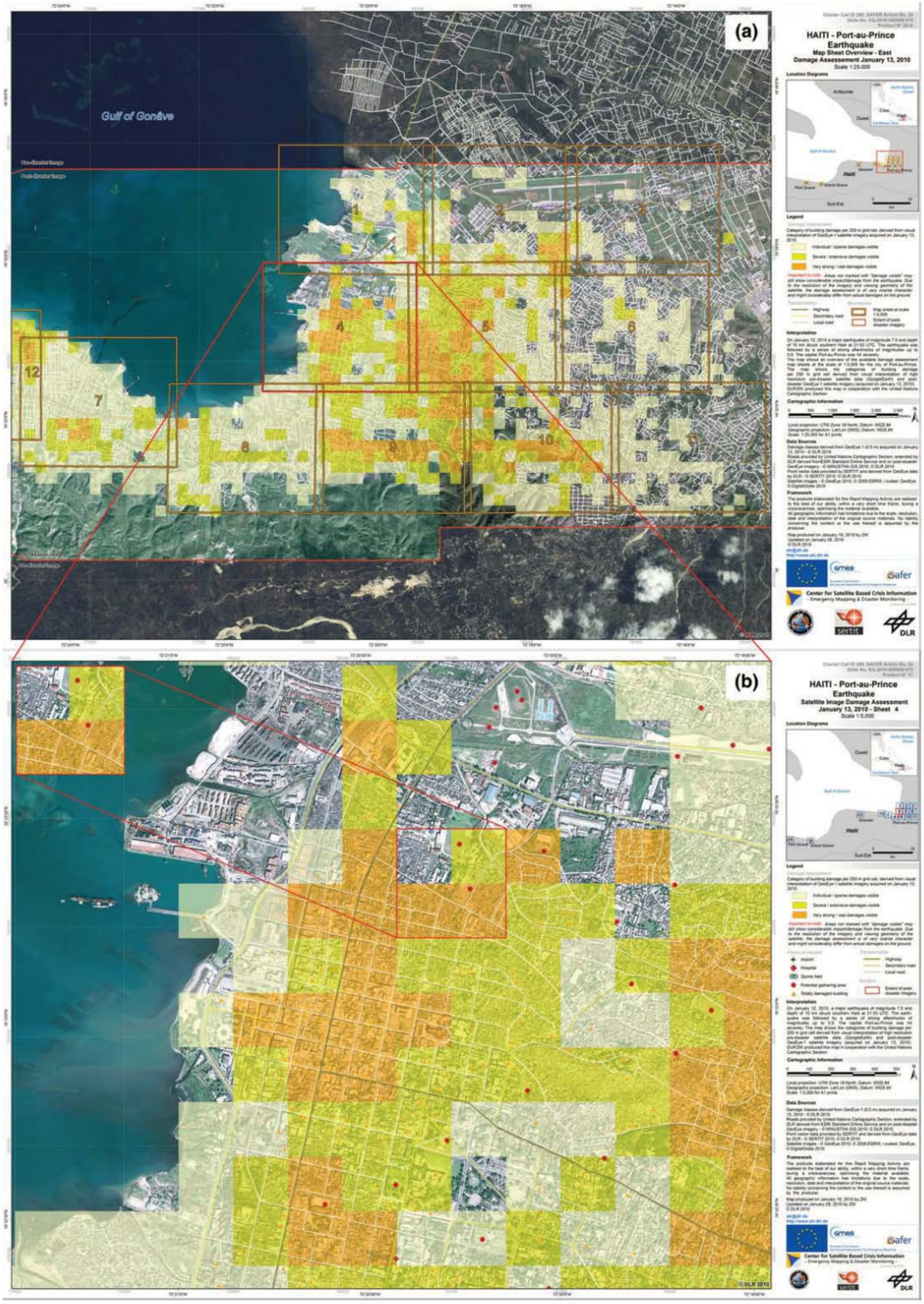


Plate 1. Results of the damage assessment: (a) DLR/ZKI: damage assessment overview map, area of Port-au-Prince, Haiti (**http://www.zki.dlr.de/map/1194**), and (b) result of the damage assessment, Haiti - Port-au-Prince, Sheet 4 (**http://www.zki.dlr.de/map/1226**).

DLR/ZKI adopted the well-established European Macroseismic Scale (EMS-98) classification scheme, depicted in Figure 3, to support and guide the image interpretation work by the image analysts.

For both, qualitative and quantitative methods, it is important to note that there are different approaches to define the reference area, which in turn strongly influences the mapping and visualization results. For instance, the reference area can either be defined as the total area of the grid cell or can be restricted to only include built-up areas within the grid cell and for any quantitative damage assessment approach this reference needs to be clearly defined.

Experiences gained during various rapid mapping operations for earthquake disasters have shown that for such extreme events, visual interpretation combined with qualitative damage categories should be preferred over automated algorithms and quantitative approaches for the first rapid assessment for several reasons: interpretability, reliability, and timeliness. For the DLR/ZKI assessment work up to 20 image analysts worked collaboratively and in close synergy to derive the qualitative damage of the build-up areas, based on grid cells, taking the EMS damage classification (Figure 3) as guiding categories: no damage, individual/sparse damage visible, severe/extensive damages visible, and very strong/vast damages visible. The classes were redefined in order to account for general limitations of satellite information content. For instance, non-structural damages are nearly impossible to detect from space. As a result of the (near-) nadir satellite viewing geometry it is sometimes not possible to detect even completely destroyed buildings, when the roof has remained intact.

The visualization of the predefined damage categories was based on a semitransparent color overlay, where light-yellow-colored grid cells show those areas with individual and dark-orange-colored grid cells account for very strong damage in built-up areas. Furthermore, completely destroyed houses were marked using point symbology.

Generally, there are several aspects which should be discussed and harmonized regarding the analysis and visualization of earthquake damages. When mapping damages in relation to the built-up area, a grid-cell with only one single building in it, and this building being completely collapsed, would be marked with the same damage level as a grid-cell with all, e.g., 75 buildings in it, totally collapsed. To correct this inadequacy, a measure representing the density of the buildings or the total number of buildings within a grid square needs to be introduced. As an alternative to a grid-based analysis approach, other spatial representation schemes like building blocks could be considered depending on the settlement structure.

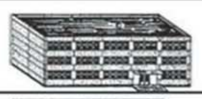
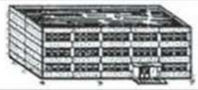
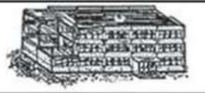
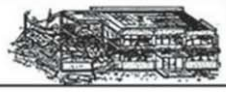
Damage Pattern	Damage Level
	Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)
	Grade 2: Moderate damage (slight structural damage, moderate non-structural damage)
	Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage)
	Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)
	Grade 5: Destruction (very heavy structural damage)

Figure 3. Classification of damage to reinforced concrete buildings (EMS, 1998)

The aspects mentioned above require continued and more in-depth research and operational harmonization for comparable international rapid satellite based damage mapping. In this context, DLR/ZKI is currently preparing a guideline for the standardized and harmonized visual damage assessment of earthquakes. As different validation efforts of map products for Haiti have shown (Lemoine, 2010; Shankar *et al.*, 2010), there is a need in the international rapid mapping community to discuss, elaborate, and harmonize the analysis and visualization approaches. Such a process could be beneficial in order to reduce the products' variability, increase the mapping accuracy, and facilitate an easier interpretation and reading of such maps by user community.

Learning From Haiti - Considerations and Suggestions for Improved Global Coordination The Haiti "Mapping Challenge"

The Haiti earthquake from January 2010 was an extreme event in its nature, with a high number of victims and a devastating impact on the capital city of a country in a fragile part of the world. Due to the dimension of the event, many organizations engaged immediately to help in the support and relief work. Also in the satellite rapid mapping domain, a fast activation of the International Charter on Space and Major Disasters, the activation of the European GMES Emergency Response Service as well as the ad hoc mobilization of a multitude of satellite resources and mapping capacities have taken place and resulted in large amounts of satellite imagery and airborne data. These data became freely available through different web resources and portals during the days and weeks following the event. Based on this imagery, global networks, a large number of individual centers, NGOs, UN bodies, as well as internet communities started to generate analysis and mapping products.

The mobilization of these resources and the availability of even very high (sub-meter) resolution imagery using the internet within a few days and weeks after the event were extraordinary. The many maps and visualizations facilitated a general understanding of the situation as well as the assessment of detailed aspects of the disaster and the relief work, including for example damage overview, road and infrastructure accessibility, gathering areas, strategic holding areas, etc. A multitude of websites and platforms hosted the maps, which however, from a certain point in time on, resulted in an overflow of mapping and satellite imagery. As a result, parts of the user community got in a difficult situation when having to determine where to look for the best and most accurate information based on mapping from space resources. Within days and weeks, even hundreds of satellite mapping products were made available on ReliefWeb, mirroring information from the different websites and platforms in the internet. The vast number of satellite maps, as well as the fact that the mapping was largely differing in style, visualization approach, image analysis, and representation of the content resulted in a drastic overflow of mapping. Even if similar things/features were mapped, e.g., damage severity, the representation of the results on the maps was often largely diverging if not contradicting or misleading. Analyzing only the UNOCHA ReliefWeb Map section it became clear that during the first four weeks following the Haiti earthquake event as many as 380 satellite maps were published on this platform (see Figure 4) coming from 34 different producers/sources.

Many of those satellite maps were generated in different ways, visuals and representations. There were reference maps, damage assessment maps, situation maps, overview maps, and further specialized maps at scales, from 1:5000 to 1:500 000 on ReliefWeb. The sheer number and diversity of mapping made it extremely difficult, if not impossible, for the relief workers and decision makers to pick the most suitable and best quality maps, meant to support their work (see Kerle, 2011). Due to these problems, the huge satellite resources, the good will, time, money, and man-power mobilized and invested in the satellite-based mapping resulted in a partially chaotic or at least "challenging" mapping overflow. It is important to reflect on this and try to learn a lesson from the Haiti event in order to improve global collaboration in such extreme cases in the future.

General Considerations and What can be Improved

Learning a lesson from Haiti, during such extreme events, and taking an increased availability of space-based and airborne imagery for a large group of actors into account, an improved coordination and harmonization of global mapping efforts is mandatory. At the same time, it is quite evident that a global coordination framework for such extreme events should not interfere with or impede all the nationally or regionally organized rapid mapping activities and operations. This means that the vast majority of the global satellite rapid mapping efforts conducted by organizations and mechanisms under specific requirements and within national or regional frameworks for local disaster situations should remain unchanged by a global harmonization framework. All these regional and national activities are assumed to be guided and governed under respective local contracts, quality assurance mechanisms or supervision, etc. Therefore, in case of extreme events triggering off a global response and a global activity in the global satellite mapping community, an improved cooperation and synergistic use of the available resources should be achieved, so that the capacities are better aligned with each other and that the resources invested can be used synergistically for the global and international relief efforts.

Reflecting the global Haiti mapping response, it can be stated that too many maps were generated by too many actors, showing too similar things in too many different ways. If all organizations involved and active in this terrible situation would have committed some part of their capacities to a globally coordinated and standardized processing and map generation process, with clear quality assurance, processing and analysis guidelines, with cross-validation and data/information sharing procedures, as well as with proper and commonly agreed mapping and visualization rules, there would not have been such an overflow of mapping, confusing the user community.

Over the past ten years, the community has made good progress in the field of satellite-based rapid mapping - mechanisms such as the International Charter Space and Major Disasters, GMES/ERS, UN-SPIDER, Sentinel Asia, etc., have greatly improved the availability of satellite imagery as well as the mapping capacity on a global basis. Generally speaking, the availability of and knowledge about GIS systems have greatly improved over the past years, resulting in a widespread knowledge on how to extract information from satellite imagery and how to produce relevant mapping products. Within all these individual rapid data provision and mapping mechanisms already a lot of efforts have been made towards standard operation procedures and harmonization of analysis work and products.

As the fast access and skills to process imagery becomes more and more commonplace (see Kerle, 2011), the community has to take a next step in moving from an *ad hoc* and best effort cooperation to a more structured and harmonized way of jointly generating and contributing space-based information to the global relief efforts in case of extreme disaster situations like the Haiti event. Having said this, it is not intended to suggest or form a new, monolithic body/organization that imposes global procedures and rules of space based disaster or crisis situation assessment. Moreover, it is envisaged and suggested to jointly and

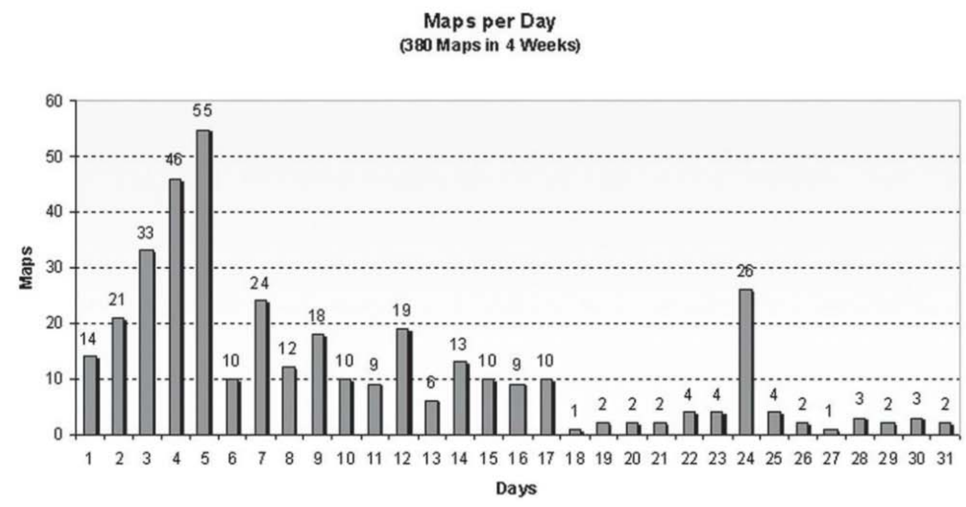


Figure 4. Number of satellite maps published on UNOCHA ReliefWeb in the days following the Haiti earthquake of 12 January 2010. Within four weeks 380 satellite maps were published in this portal, 169 of these within the first five days.

collaboratively establish in a bottom up approach, globally-accepted rules of engagement, basic satellite emergency mapping standards, and slim coordination tools in order to harmonize and optimize a global satellite geospatial mapping response for extreme disaster events. Such generally accepted rules may also positively impact on other fields of crisis mapping in the geospatial sector, however, the utmost importance is to start making the next step towards a first and simple guideline and rules of engagements for collaborative rapid emergency mapping work.

Towards a Global Cooperation and Harmonization Procedure

The general vision of an improved global cooperation and harmonization is to establish a set of simple and clear guidelines, possibly formulated in a handbook, possibly similar to the INSARAG guidelines (INSARAG, 2006) or the UNDAC handbook (UNOCHA, 2006) established for the international cooperation in the urban search and rescue community. Such guidelines and best practices should describe in a simple, non-discriminating and clear way, how global efforts in space-based emergency mapping should best be coordinated and carried out in order to not impose on any party involved. The guidelines should describe how to structure the overall collaboration and performance in this context. As an important initial step, a guideline would need to define the exact scope and the actors it addresses, as the domain is wide spread and diverse, ranging from professional rapid mapping centers, NGOs, industry, academia, individual, and internet communities to space agencies or other governmental bodies. Based on these definitions, rules for qualification, exercising and certification of the different capacities could be established, since the slim, bottom-up coordination can only work if all involved actors know the few rules governing the mechanism and if the actors are well trained and ready to work along those commonly-developed and accepted regulations. Basis for these trainings and exercises will be a set of simple procedures and best-practices for the key parts of the data handling and map generation chain, which will allow modular and global interaction between the different centers and organizations involved. Key elements that should be addressed by those procedures are the triggering, requesting, and communication among the mechanisms and capacities, simple and basic handling, and processing steps for the satellite data (geometry, projection, file formats, etc.), basic rules, and guidelines for analysis and image interpretation, including set of standard interpretation keys and legends for main damage assessment or topographic features.

For the data provision part of this, the International Charter may play a significant role for the coordination, while for the map producing part this will allow the work of different actors and capacities to become comparable and compatible at global scale. Furthermore, this will be a key basis to derive quality-controlled, validated, and coherent information products from satellite imagery in a fast, transparent and global manner. The same applies for basic visualization and mapping standards with a basic set of symbologies and visuals. It is well understood that there are cultural differences and different visual communication styles all over the world; however, to achieve a basic global cooperation in satellite-based emergency mapping, a few fundamental rules need to be established in order to allow interchange, validation, and comparison of analysis results and mapping products. Furthermore, a basic understanding will have to be established in such a framework, on how to exchange and share data, products and information, on a voluntary basis, as there will be no exchanges of funds between involved partners and neither formal nor legally binding regulations. Thus, the whole framework presumably will have to be organized in a shared responsibility of the involved actors, ready to respect a few basic rules and guidelines, e.g., on mutual quality assurance and distributed validation procedures based on in-field information, cross-validation of analysis results by different, redundant producers of individual pieces of information or assessments, etc. Finally, such a framework can only exist on a permanent basis if the rules governing the interaction of the players and capacities are routinely reviewed and commonly improved for example by a globally accepted advisory group.

In order to bring forward such a mechanism, an international working group on global harmonization and cooperation in satellite-based emergency mapping for extreme disasters situations is suggested. The working group should elaborate and agree on a set of practical and operational rules of engagement and operation. The working group could be facilitated by the UN-SPIDER program, making use of this global network and the respective platforms and mechanisms, as well as, it should be established with mandated delegates from interested nations. The working group should elaborate and agree such guidelines, best practices, and rules of engagement as well as it could observe and review the successful implementation and success of the cooperation framework during yearly hearings.

Conclusions

In conclusion it can be summarized that the Haiti event was extreme in its character and scale and that the global satellite based emergency mapping community should learn from this event. Based on the experience made at DLR/ZKI during this event the large work load and effort put into the analysis of satellite imagery and mapping can only be compared to that of very few extreme events during ten years of satellite based crisis and disaster mapping at DLR. As presented and discussed above, the task of rapid satellite based assessment of earthquake damages remains difficult and challenging and probably will have to remain qualitative in its character, when using space-borne image data until more robust and automated methods become available. Even if the satellite imagery has a spatial resolution of 50 cm, it is still difficult to derive absolute and quantitative damage figures within hours and days. Scientific work and studies will have to be intensified in deriving better, faster, and more robust methods for effective qualitative, and if at all feasible, quantitative rapid earthquake damage assessment from space based imagery.

Building on the experiences gathered in the aftermath of the Haiti event, it can be concluded that the global community in satellite based emergency mapping should take a next step, moving from an *ad hoc* cooperation, without clear rules of engagement and without any guidelines, to a more structured and coordinated way of collaboration. The community is mature enough to take this next step, and an international working group should be established to derive and continuously review such commonly accepted rules and collaboration procedures for rapid satellite-based emergency mapping for extreme disaster and crisis events.

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